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annular radial seal, which is configured to slidably engage the rotating shaft has a thickness, and a length being ~~greater than and less than about~~ from about 1 to about 15 times greater than the thickness.

[0025] In various embodiments, the dynamic seal 10 is formed of a processable rubber composition[[s]] comprising a vulcanized elastomeric material dispersed in a matrix. The vulcanized elastomeric material is the product of vulcanizing, crosslinking, or curing a fluorocarbon elastomer. The matrix is made of a thermoplastic material containing at least one ~~containing~~ thermoplastic polymer. The processable rubber compositions may be processed by conventional thermoplastic techniques to form dynamic seals having physical properties that make them useful in a number of applications calling for elastomeric properties.

[0027] As can be seen in Figure 2b, the dynamic seal 10b ~~an~~ can have a bearing surface 20b which is substantially variegated. In this regard, a spiral groove 24 is formed onto a portion of the flat bearing surface 20b. It is envisioned that there can be between 5 and 200 grooves per inch, and these grooves would cover between 10 and 90%, and preferably 25-75% of the flat bearing surface. The number of spiral grooves which contact with the shaft surface is between 1 and 10, and preferably between 1 and 3 grooves in contact with the shaft.

[0030] In particular preferred embodiments, a dynamic seal 10 is made from the processable compositions, which typically exhibit a Shore A hardness of 50 or more, preferably Shore A 70 or more, and typically in the range of Shore A 70 to Shore A 90. In addition or alternatively, the tensile strength of the dynamic seal will preferably be 4 MPa or greater, preferably 8 MPa or greater, and typically about 8-13 MPa.

[0032] In various embodiments, the dynamic seal 10 is formed of a rubber composition comprising two-phases, where the matrix forms a continuous phase, and the vulcanized elastomeric material is in the form of particles forming a non-continuous, disperse, or discrete

phase. In another aspect, the dynamic seal 10 is formed of elastomeric material and the matrix forms co-continuous phases. The ~~compositions~~ composition of the elastomeric material contains 35% by weight or more, and preferably 40% by weight or more of the elastomer phase, based on the total weight of elastomer and thermoplastic material. Optionally, the ~~compositions~~ composition contains 50% by weight or more of the elastomer phase. The elastomer phase may be present in the form of particles in a continuous thermoplastic phase, as a 3-D network forming a co-continuous phase with the thermoplastic material, or as a mixture of both. The particles or 3-D network of the elastomer phase preferably have minimum dimensions of 10 μm or less, and more preferably 1 μm or less.

[0033] The dynamic seal 10 may be formed of a rubber composition which is made by dynamic vulcanization of a fluorocarbon elastomer in the presence of a thermoplastic component. In this regard, the method for producing a dynamic seal is provided. The formation of the seal begins with combining a curative agent, an elastomeric material, and a thermoplastic material to form a mixture. The mixture is heated at a temperature and for a time sufficient to effect vulcanization or cure of the fluorocarbon elastomer in the presence of the thermoplastic material. Mechanical energy is applied to the mixture of elastomeric material, curative agent and thermoplastic material during the heating step. The elastomer and thermoplastic components are heated in the presence of a curative agent ~~and heating~~ during the mixing to effect cure of the elastomeric component. Alternatively, the elastomeric material and thermoplastic material may be mixed for a time and at a shear rate sufficient to form a dispersion of the elastomeric material in a continuous or co-continuous thermoplastic phase. Thereafter, a curative agent may be added to the dispersion of elastomeric material and thermoplastic material while continuing the mixing. Finally, the dispersion is heated while continuing to mix to produce the processable rubber composition of the invention.

[0035] At the same token, the ratio of loss modulus to storage modulus is desirable to be less than 0.1. The ratio is typically described as a tangent delta value with DMTA (Dynamic Mechanical Thermal Analyzer). Again, the elastomeric materials usually show less than 0.1 value; however, plastic materials exhibit equal or greater than 0.1 due to more viscosity contribution than elastomeric contribution of typical visco-elastic behavior of plastic materials. The typical value of PTFE plastic is greater than 0.1, especially at the phase transition temperatures (20°, 120°, etc.). However, the long and curved lip design tend to compensate to prevent "bellmouthing" behavior. TPU and TPE type thermoplastic materials according to the present invention can function as a dynamic seal by applying proper design to compensate for the lack of desired material properties, which could cause for leakage due to "bellmouthing" properties of plastic-like materials. The long and curved lip design, and associated reinforcement structure at the end of lip seal, and loading of a spring at the tip of the lip seal ~~features proposed to compensate~~ compensates for the lack of desirable material properties for dynamic seal applications. In this regard, it is preferable that the ratio of loss modulus to storage modulus of the material used in the seal is less than ~~1.0~~ 1.0, and most preferably less than ~~1.0~~ 0.1.

[0038] The compositions of the invention are preferably processable by conventional plastic processing techniques. In another embodiment, a dynamic seal is provided comprising the cured, fluorocarbon elastomers dispersed in a thermoplastic matrix. Preferred fluorocarbon elastomers include commercially available copolymers of one or more fluorine containing monomers, chiefly vinylidene fluoride (VDF), hexafluoropropylene (HFP), tetrafluoroethylene (TFE), and perfluorovinyl ethers (PFVE). Preferred PFVE include those with a C₁₋₈ perfluoroalkyl group, preferably perfluoroalkyl groups with 1 to 6 carbons, and particularly perfluoromethyl vinyl ether and perfluoropropyl vinyl ether. In addition, the copolymers may also contain repeating units derived from olefins such as ethylene (Et) and propylene (Pr). The

copolymers may also contain relatively minor amounts of cure site monomers (CSM), discussed further below. Preferred copolymer fluorocarbon elastomers include VDF/HFP, VDF/HFP/CSM, VDF/HFP/TFE, VDF/HFP/TFE/CSM, VDF/PFVE/TFE/CSM, TFE/Pr, TFE/Pr/VDF, TFE/Et/PFVE/VDF/CSM, TFE/Et/PFVE/CSM and TFE/PFVE/CSM. The elastomer designation gives the monomers from which the elastomer gums are synthesized. The elastomer gums have viscosities that give a Mooney viscosity in the range generally of 15-160 (ML1 + 10, large rotor at 121°C), which can be selected for a combination of flow and physical properties. Elastomer suppliers include Dyneon (3M), Asahi Glass Fluoropolymers, Solvay/Ausimont, Dupont, and Daikin.

[0044] The thermoplastic material making up the matrix includes at least one component that is a thermoplastic polymer. This thermoplastic material can be a fluorine containing thermoplastic or a non-fluorine containing thermoplastic. The polymeric material softens and flows upon heating. In one aspect, a thermoplastic material is one the melt viscosity of which can be measured, such as by ASTM D-1238 or D-2116, at a temperature above its melting point.

[0068] In some embodiments, the cured elastomeric material is in the form of particles forming a dispersed, discrete, or non-continuous phase wherein the particles are separated from one another by the continuous phase made up of the thermoplastic matrix. Such structures are expected to be more favored at relatively lower loadings of cured elastomer, i.e. where the thermoplastic material takes up a relatively higher volume of the compositions. In other embodiments, the cured material may be in the form of a co-continuous phase with the thermoplastic material. Such structures are believed to be favored at relatively higher volume of the cured elastomer. At intermediate elastomer loadings, the structure of the two-phase compositions may take on an intermediate state in that some of the cured elastomer may be in the